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DAMAGE TO BLACK SPRUCE CONE CROPS BY THE SPRUCE BUDWORM

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ABSTRACT

A low spruce budworm (Choristoneura fumiferana) population level that caused only light defoliation significantly reduced cone production on black spruce trees. Larvae emerging from hibernaculae preferred male and female flowers over vegetative buds and new shoots as feeding sites. Mortality of female flowers varied from 0 to 100% for individual trees but averaged 24%. Additional feeding damage occurred on immature cones. Some cones matured but many had irregular shapes as a result of budworm damage. Less than 15% of mature cones with more than one-quarter of the scales damaged by feeding produced viable seed. Some cones were also damaged by the spruce cone worm (Dioryctria reniculleloides). The tops were removed from 34 trees to record shoot growth and number, to assess budworm damage and to count the insects and cones at various stages of their development.

RÉSUMÉ

Une population peu élevée de la tordeuse des bourgeons à l'épinette (Choristoneura fumiferana) qui n'a provoqué qu'une défoliation légère a pourtant réduit la production des cônes sur les Epinettes noires. Les larves à la sortie des hibernacles choisissaient les fleurs mâles et femelles plutôt que les bourgeons végétatives ou les pousses nouvelles comme lieu de nourriture. La mortalité des fleurs femelles variait de 0 à 100% pour les arbres individuels mais était de 24% en moyenne. De plus on a noté des dommages causés à des cônes pas mûres. Quelques cônes ont mûri mais beaucoup avaient des formes irrégulières comme suite des dommages causés par la tordeuse. Moins de 15% des cônes mûres qui avaient plus d'un quart des écailles gachées par la tordeuse produisaient des graines valables. Quelques cônes ont reçu leurs dommages de la tordeuse des cônes à épinette (Dioryctria reniculleloides). On a coupé la faîte à 34 arbres pour noter le nombre et la grandeur des pousses, pour evaluer les dommages de la tordeuse et pour compter les insectes et les cônes aux divers stages de leur développement.

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INTRODUCTION

The spruce budworm (Choristoneura fumiferana (Clem.)) is a major factor influencing the production of cone crops on balsam fir (Abies balsamea (L.) Mill.) (Powell 1973, Schooley 1978). Not only are cone flowers and immature cones damaged but defoliation by this insect also reduces cone production by lowering tree vigor and limiting the number and length of shoots upon which reproductive buds may develop. The literature also outlines the influence of budworm feeding on the cone production of white spruce (Picea glauca (Moench) Voss.) (McLeod and Daviault 1963, Tripp 1950).

In Newfoundland the Provincial Forest Service has been unable to obtain sufficient black spruce (Picea mariana (Mill.) B.S.P.) seed for their tree nursery and silviculture programs. An abundant cone crop expected to occur throughout most of the Island in 1976 was not produced. Observations suggested that the severe spruce budworm infestation in much of the Island's forest area was limiting the production of cones on black spruce as well as on balsam fir.

The normal cone bearing characteristics of black spruce have been summarized by Vincent (1965) and Safford (1974). Cone production is common on 15 year old trees and tends to increase with age up to about 100 years. Good cone crops occur at intervals of 2 to 6 years but

there are usually some cones produced each year. Reproductive buds appear on the current season's shoots and develop into cones the following year. Cones normally occur on the periphery of branches in the apical five feet of the crown. Mature cones are 1 to 4 cm long, ovate when closed and nearly spherical when open. They are usually attached to the upper side of twigs but hang downward. Cones ripen in one season and remain on the trees for many years. The old cones are often the source of seed required to regenerate stands after harvesting or fire.

This report describes the effects of the spruce budworm on cone production by black spruce.

COLLECTION OF DATA

The effect of spruce budworm damage on cone production was examined on trees from two locations; Lake Ambrose, in central Newfoundland, and Stephenville, in western Newfoundland.

Lake Ambrose

Ten years of top growth was collected from two merchantable black spruce trees at Lake Ambrose. These trees had been severely defoliated by the spruce budworm in 1976 and had been lightly defoliated in several previous years. The number of cones, partially developed dead cones and latent buds* produced each year were recorded. The

*Latent buds cease growth after forming bud scales but are potentially active (Owens 1969).

history of annual shoot elongation and branch production was also recorded along the mainstem and along all primary branches of each branch whorl.

Stephenville

Cone production was studied on cone bearing trees in a 40-45-year old stand located near Stephenville in western Newfoundland in 1977. Defoliation by the spruce budworm in this stand was classified as light in both 1976 and 1977. The cone crop was assessed on 32 trees; 7 on June 21, 9 on July 8, 7 on August 10, and 9 on September 27. These trees were selected on the basis of their having 1977 cone flowers (June), immature cones (July and August), and mature cones (September). The tops of these trees were removed and examined. The cones at various stages of development and the insects present were counted, cone lengths were measured, and the percentage of cone scales damaged by spruce budworm was recorded. Cones were cut longitudinally in half, then internal damage by cone insects was estimated, and the apparent viability of the exposed seed was assessed on the basis of endosperm condition (Dobbs et al. 1976). Cones produced in 1976 were also counted and examined for insect damage.

RESULTS AND DISCUSSION

Lake Ambrose

Twice the number of reproductive structures were present in 1976 as in 1974 on both trees from Lake Ambrose (Table 1). In 1974 nearly all reproductive buds developed into mature cones but in 1976 40%

on one tree and 25% on the other tree were killed in the cone flower stage or as very young, immature cones. Many of the cones that matured were scarred by insect larval feeding.

Table 1. Reproductive bud development leading to cone production in 1974 and 1976 on two black spruce trees severely defoliated by spruce budworm in 1976 near Lake Ambrose.

	Tree 1		Tree 2	
	1974	1976	1974	1976
Number of (reproductive) buds becoming latent	0	0	0	9
Number of dead cone flowers and immature cones	1	230	2	300
Number of mature cones	232	351	546	814
Total number of reproductive structures	233	581	548	1123

The annual growth and number of shoots in 1975 and 1976 decreased compared to similar data from 1973 and 1974 (Table 2). Most of the reduced shoot increment recorded in 1976 occurred as a direct effect of severe defoliation that year. However, the several years of light defoliation before 1976 appear to have lowered the overall vigor of the trees. This probably caused the reduced length and number of shoots observed for 1975 and could have contributed to 1976 reductions as well. A reduction in shoot increments is expected to lower the potential for cone production on the trees by limiting the number of

locations where cones usually occur. Although these two black spruce trees did not exhibit the expected reduction in cone production, it probably occurs on trees that have been more intensely damaged by the budworm. Such a reduction occurs in balsam fir (Schooley, 1978) where the quantity of cones is inversely related to the severity and the number of years of defoliation.

Table 2. Average length and number of shoots produced from 1973 to 1976 on two black spruce trees severely defoliated by spruce budworm in 1976 and lightly defoliated in several previous years near Lake Ambrose.

	Year			
	1973	1974	1975	1976
- average length of main stem terminal (cm)	15	10	4	2
- % of primary nodal branches with terminal growth (N = 30)	67	63	27	17
- average length of primary branch terminals (cm)	7	6	3	3
- average number of primary whorl branches	4	3	2	1
- average number of primary internodal branches	12	17	3	3
- average number of secondary nodal branches	0.9	0.7	0.6	0.3
- average number of secondary internodal branches	2.8	4.4	1.6	0.3

Stephenville

In June the stage of development of the vegetative buds on different trees ranged from swollen, but not open, to 75% of buds flushed. At this time the cone flowers were completely formed and fertilization was taking place. In July the vegetative buds had flushed on all trees and it was estimated that 30 to 80% of shoot elongation was completed. Female flowers that had not been killed were developing into cones.

The amount of damage to the foliage in June was very small. About 28% of the 2,518 vegetative buds or newly developing shoots examined were mined (Table 3). However, there were nearly five times as many mines as larvae and much of the mining was not extensive. This suggests that the larvae had been quite mobile or unsettled - more so than was expected when there was no competition for feeding sites. Most of the larvae collected from the shoots were in their third or fourth instar and no dead larvae were found.

In June, the reproductive structures were favoured over the vegetative buds and shoots as feeding sites by budworm larvae (Table 3). Larvae had damaged 94% of female flowers and 87% of male flowers. Records also show that about one quarter of the total larvae counted were harbored within cone flowers even though these structures accounted for only a small portion of the food source available to the larvae. Table 3 further indicates that larvae feeding on cone flowers develop

Table 3. The number and stage of spruce budworm larvae feeding on 1977 vegetative buds or shoots, male and female flowers in the 1974 to 1977 segment at the top of 7 black spruce trees in June near Stephenville.

	Number examined	Number mined	Number and stage of mining budworms present			Number mined without larvae	Number of exposed budworm feeding on the shoots		Total larvae
			3 instar	4 instar	5 instar		4 instar	5 instar	
1977 vegetative buds or shoots	2,518	709	87	45	4	573	23	4	163
1977 male flowers	23	20	0	0	0	20			0
1977 female flowers	151	142	12	32	1	97			45

more rapidly than those feeding on the foliage: 73% of larvae collected on female flowers were in the 4 or 5 instar while only 26% mining the buds or shoots were at this stage of development. A similar accelerated development occurs when larvae feed on the staminate flowers of balsam fir (Greenbank 1963).

Initial budworm feeding usually stripped the developing cone bracts and ovuliferous scales from the cone axes rather than girdling the base of the axes as is common in balsam fir (Powell, 1973). The feeding on spruce did not affect the length of cone flowers unless more than 80% of the bracts and scales were consumed or damaged (Table 4). It was not possible in June to determine what proportion of the cone flowers would be killed because feeding damage was still accumulating. However, it was apparent that many of the severely damaged cone flowers would die without further development. In the July, August and September samples it was still possible to recognize budworm killed cone flowers. The loss in cone production at the flower stage varied between 0 and 100% for individual trees and averaged 24% for the 25 trees sampled. The average length of 312 dead cone flowers measured was 10 mm.

In July late instar budworm larvae were feeding on the foliage and both prepupal larvae and pupae were present. Budworm populations were not assessed for the whole tree tops sampled but observations indicated that from one-third to one-half of the larvae and pupae present were within mined-out 1977 immature cones or in webbing beside the cones. On the average there was one cone-feeding budworm for every six

Table 4.- Average length of cone flowers and immature cones collected near Stephenville and grouped into damage classes.

	% of flower or cone damaged or consumed									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Cone flowers examined June										
number	39	16	20	15	6	13	19	12	8	3
average length (mm)	11	12	12	12	12	11	10	10	9	7*
Immature cones examined July										
number	41	17	24	22	8	22	16	15	15	21
average length (mm)	22	20	17	17	16	17	17	16	14	14*

*frequently only the flower or cone axes were present.

cones on the trees. This is about one-half the ratio of larvae to cones, established for the June samples. Cones with irregularities or cavities in their surface caused by early feeding were favoured resting places and considerable additional damage was done to these cones by the late instar larvae. The additional feeding damage occurred while the cone scales were developing. In all but the least damaged class, feeding resulted in abnormally shaped cones. Killed or damaged scales were often present on only one side of the cones and the shape of cones became distorted and dented as the undamaged scales continued to grow.

In addition to the spruce budworm the spruce cone worm, Dioryctria reniculelloides, Mutuura and Monroe was also damaging immature cones in 1977. The cone worm's feeding habits and damage were similar to those of the budworm. Of all larvae observed near the cones in July, 15 to 17% were spruce cone worms. On the average there was one cone feeding cone worm or budworm larvae for every five immature cones on the trees. These observations indicate that further investigation of this insect is warranted. The cone worm like the budworm may also be a serious pest of black spruce cones in Newfoundland.

The average length of the least damaged immature cones collected in July was 22 mm (Table 4). More than 20% of the scales were damaged on nearly three-quarters of the cones examined and these were much shorter (< 17 mm) than other cones with less damage. The one-third of the cones with more than 70% damage appeared certain to die without further development. Furthermore, it was expected that many other immature

cones would also die before the budworm and cone worm feeding was completed. This expectation was confirmed by the August data. The total cone crop on all seven trees sampled was killed by larval feeding when cones were in the flower or immature stages.

The severity of damage to 1977 cones that matured is apparent from the collections made in September (Table 5). More than one-quarter of the cone scales were damaged or missing on 84% of the mature cones. Both the average length of cones and the percentage containing at least one viable seed decreased as the amount of damage to the cones increased.

The spruce budworm was clearly not the only pest of black spruce cones. Other insects, feeding within the cones without any apparent regard for the budworm, caused significant losses of seed. The cones with fewer than half of their scales damaged by the budworm should have produced seed (Table 5). However, only about one-fifth of these cones had viable seed. Dipterous insects caused most of this seed loss; damage by the spruce cone maggot, Hylemya sp. was the most common and extensive.

All the trees examined in 1977 had produced cones in previous years and all but two produced cones in 1976. The length of 1976 cones was related to damage (Table 6) in the same way as 1977 cones (Table 5). However, 1976 cones were slightly longer than 1977 cones in all damage classes. This greater length in 1976 is probably a result of better growing conditions or higher tree vigor in that year rather than an effect directly attributable to spruce budworm feeding. The trees sampled were only lightly defoliated in 1976 and 1977.

Table 5. The percentage of living mature cones collected near Stephenville in September 1977 from nine black spruce trees in four cone damage classes and the average length and percentage of cones with viable seed in each damage class.

	Damage classes			
	0-24% of cone scales damaged	25-49% of cone scales damaged	50-95% of cone scales damaged	Few scales present
% of 1977 cones (N = 273)	16	27	45	12
Average cone length (mm)	24	21	18	13
% of cones in each class with viable seed (estimated)	30	15	5	0

Table 6. The percentage of 1976 cones from 30 black spruce trees in four cone damage classes and the average length of cones in each damage class near Stephenville.

	Damage classes			
	0-24% of cone scales damaged	25-49% of cone scales damaged	50-95% of cone scales damaged	Few scales present
% of 1976 cones (N = 1496)	37	22	36	5
Average cone length (mm)	26	23	18	15

Precise estimates of seed production by 1976 cones were not possible on most trees because the cones had shed their seed. However, most of these cones were sufficiently damaged internally by cone insects other than the budworm to have prevented production of viable seed. One tree with 106 cones had not shed its seed. About half of these cones were severely damaged by cone insects such as the spruce cone maggot and only 21 cones that were not damaged by these insects had viable seed. The damage by cone insects was not related to the amount of spruce budworm damage apparent on the cones of this specially noted tree or on the 1976 cones from any other tree.

SUMMARY

A pronounced decrease in cone production by black spruce was caused by spruce budworm feeding. A low budworm population level that caused only light defoliation of the trees significantly reduced cone production. Reproductive buds were not damaged because the budworm larvae emerged from hibernaculae after these buds had flushed. However, flowers were favoured feeding sites over vegetative structures. Only 28% of the vegetative buds or new shoots were fed upon but 94% of female and 87% of the male flowers were damaged.

In June feeding larvae occurred on about one-third of the female flowers. The loss of cone production at the flower stage varied between 0 and 100% for individual trees and averaged 24%. In July an estimated one-third to one-half of the late instar larval and pupal population were found within mined cones or in webbing beside the cones. Immature cones with irregularities in their surface caused by earlier

feeding were favoured resting places and considerable additional damage was being done wherever larvae were present. More than one-quarter of the scales were damaged or missing on mature cones examined in September. Both the average length of cones and the percentage that contained viable seed decreased as budworm damage increased.

Damage, similar to that of the budworm, was caused by the spruce cone worm, Dioryctria reniculelloides. Since this insect species occasionally occurs in large numbers, it could, like the budworm, be a serious pest of cones. Concurrent damage to the interior of cones by insects such as the spruce cone maggot appears to also greatly reduce seed production.

Black spruce trees severely defoliated by the spruce budworm for one year and with a history of previous light damage showed large reductions in the length and number of new shoots produced. It was not demonstrated in this study that these decreases in shoot increments reduced cone production. However, reductions in cone production for this reason have been shown for balsam fir (Schooley 1978) and probably also occur on black spruce that has been more intensively damaged than the trees examined.

The data on cone damage given in this paper aptly demonstrates that during a severe spruce budworm outbreak it will be difficult to procure the black spruce seed required for silvicultural and nursery work. Also, depletion of black spruce seed by the budworm and other cone pests may very well cause serious problems in the natural regeneration of this tree species.

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